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CONTENTS

30 Research into the causes of fire in Hiroshima and Nagasaki, combined with a study of the secondary fire risk from the flying bomb damage in this country during the last war has shown that with nuclear attack the secondary fire risk is likely to be small compared with the primary risk of direct ignition by thermal radiation.

Fire precautions

31 Although the fire risk even from a nominal bomb is always serious, targets in this country, where the great majority of buildings are of brick, stone or concrete, are less vulnerable to fire than were those in Japan, where most of the buildings were of wood. Moreover, if people do what they can to keep heat radiation out of buildings, the risk of fire can be further reduced, although these precautions would be effective only beyond the central area of blast destruction (see Chapter IV).

32 It might be advisable to brick up certain windows of important buildings, but since the thermal radiation has no great penetrating power, any opaque screen, especially a white one, will keep it out: the simple process of whitewashing windows will keep out about 80 per cent. of the heat. The windows may be broken by the blast wave but as this travels more slowly it arrives after the thermal radiation is over (except of course in the central area of blast destruction), whether the bomb is a hydrogen bomb or an atomic bomb.

33 Another obvious fire precaution is the removal of all readily combustible material from the direct path of any heat radiation that could possibly enter windows or other openings.

34 Both these precautions apply only to those windows and other openings that have a direct view of some part of the sky. In a built-up area they would apply more particularly to the windows of upper floors; even for a high airburst, in a closely built-up area one building shields another to a considerable extent.

The probable fire situation in a British city

35 Within $\frac{1}{2}$ mile of an airburst nominal bomb the heat flash is very intense indeed, but in this area there would be almost complete destruction of buildings by blast, and this would tend to impede the development of fire. This did not happen in Japan because most Japanese houses are constructed of wood and once they were set on fire they continued to burn even when knocked over. In this country only about 10 per cent. of all the material in the average house is combustible, and under conditions of complete collapse, where air would be almost entirely excluded, it is doubtful whether a fire could continue on any vigorous scale. The main fire zone will be around this central area of heavy destruction, in the region where buildings are damaged but standing sufficiently to allow free burning. For a nominal bomb, this zone is likely to reach as far as $1\frac{1}{4}$ miles.

36 The range of ignition is affected to some extent by the state of the atmosphere and on a dull misty day will be reduced, although it is impossible to say precisely to what degree.

The possibilities of a fire storm

37 The chief feature of a fire storm is the generation of high winds which are drawn into the centre of the fire area to feed the rising column of hot air and flames. These in-rushing winds prevent the spread of fire outwards, but ensure the almost complete destruction by fire of

everything within the fire area. This inevitably increases the number of casualties, since it becomes impossible for people to escape by their own efforts because they succumb to the effects of suffocation and heat stroke.

38 The Hiroshima bomb (but not the Nagasaki one) caused a fire storm. A fire storm occurred in Hamburg and possibly also in several other German cities as a result of accurate and very dense attacks with incendiary and high explosive bombs by the R.A.F. Information on the subject is limited, but it has been fairly well established that during these particular raids on Germany half the buildings in the target area were set on fire in about half an hour. In such circumstances it seems that nothing can prevent all the fires from joining together into one mass fire engulfing the whole area.

39 Whether a fire storm develops depends also on the nature of the target; where there are tall buildings closely packed together with plenty of combustible material to burn, the risk is much greater than in areas less densely built up.

40 It seems unlikely from the evidence available that an initial density of fires equivalent to one in every other building would be started by a nuclear explosion over a British city. Studies have shown that a much smaller proportion of buildings than this would be exposed to thermal radiation and even then it is not certain that continuing fires would develop. Curtains may catch fire, but it does not necessarily follow that they will set light to the room; in the last war it was found that only one incendiary bomb out of every six that hit buildings started a continuing fire. Moreover after a nuclear explosion the large and almost completely flattened central area would counteract the development of a fire storm, since one essential requirement seems to be a continuous mass of fire over a large area. It is unlikely, therefore, that a fire storm would develop after a nuclear attack on a British city, though the possibility cannot be ruled out. The risk can be reduced by clearing or partially clearing the top floors of buildings which are likely to be exposed to the heat radiation, and by adopting the other precautions mentioned above.

41 There would, however, in any case be many serious fires and fire areas.

Scaling laws

42 For more powerful bombs the total heat output is roughly proportional to the power of the bomb, so that a 10 megaton bomb, which is 500 times more powerful than a nominal bomb, radiates 500 times as much heat. Because of the inverse square law, the distance at which a given amount of heat is received (measured per unit area of receiving surface) varies as the square root of the power of the bomb. For example, if a nominal airburst bomb produces 5 calories per square centimetre at 1 mile, a 10 megaton airburst bomb will produce the same amount at 22 miles ($22=\sqrt{500}$). However, although at 1 mile from a nominal bomb an intensity of 5 calories per square centimetre would ignite easily combustible materials and start fires, it would not do so at 22 miles from a 10 megaton bomb because the heat is applied more slowly. From a 10 megaton bomb, with its longer lasting thermal radiation (see paragraph 21), it takes about 20 calories per square centimetre to start fires because so much of the heat (spread out over the longer emission) is wasted by conduction into the interior of the combustible material and by convection and re-radiation whilst the

temperature of the surface is being raised to the ignition point. But the distance at which 20 calories per square centimetre can be produced is only 11 miles, so that the scaling factor for a 10 megaton airburst bomb is therefore 11 and not 22.

43 For a ground burst bomb, however, several other factors contribute to a further reduction in the fire range. Apart from an actual loss of heat by absorption into the ground and from the pronounced shielding effect of buildings, the debris from the crater tends to reduce the radiating temperature of the fireball and a greater proportion of the energy is consequently radiated in the infra red region of the spectrum —this proportion being more easily absorbed by the atmosphere. The magnitude of this absorption effect is not known with certainty, but it is important in hydrogen bomb explosions because of the longer ranges involved and because—as later explained in paragraph 81—the likelihood of ground bursts has been increased with the advent of the hydrogen bomb. For all these reasons it has been estimated that the scaling factor for the fire range for a ground burst 10 megaton bomb is about 8. This will mean a fire ring extending from about $3\frac{1}{2}$ to 10 miles instead of, as in the case of a nominal airburst bomb, from $\frac{1}{2}$ to $1\frac{1}{4}$ miles. Isolated fires may occur at greater distances, depending on the combustibility of material within buildings, but it is impossible to apply precise scaling laws to such haphazard incidents.

44 An important point in relation to personal protection against the effects of hydrogen bomb explosions is that because the thermal radiation lasts so long there is more time for people who may be caught in the open, and who may be well beyond the range of serious danger from blast, to rush to cover and so escape some part of the exposure. For example, people in the open might receive second degree burns (blistering) on exposed skin at a range of 16 miles from a 10 megaton ground burst bomb (8×2—see paragraph 24). If, however, they could take cover in a few seconds they would escape this damage. Moreover, at this range the blast wave would not arrive for another minute and a half so that any effects due to the blast in the open (e.g. flying glass, etc.) could be completely avoided.

76 Because the range of gamma rays in air is much greater than that of beta rays, an appreciable part of the dose received at any one spot is made up of gamma rays coming from quite long distances; half of it comes in fact from within, and the other half from beyond, a distance of about 25 feet (see Figure 1). Shielding by buildings and other objects may help to reduce the dose rate by reducing the contribution from material some distance away; likewise, cleaning up the area close to where operations are being carried out will reduce the dose rate, but will not eliminate it altogether because of the contribution from material much farther away.

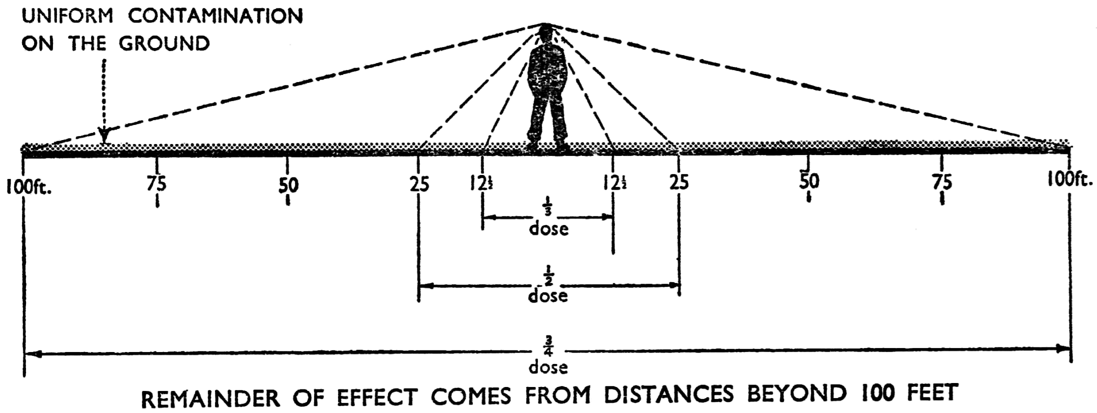

FIGURE 1

Total Dose from Fall-out—Contribution from Different Distances

Radioactive decay

77 Radioactivity cannot be destroyed or interfered with chemically, and its decay can neither be accelerated nor slowed down. The average decay rate of all the various products of a nuclear explosion is such that as the time is doubled, the activity is somewhat more than halved. More precisely, the activity is reduced by a factor of 10 when the time is multiplied by a factor of 7. For example if the dose rate at any given point one hour after an explosion is 100r/hr then the dose rates at other times will be as follows:

Time after burst	*Dose rate in r/hr*
1 hour	100
7 hours	10
49 hours (2 days approx.)	1
2 weeks	0.1
14 weeks (3 months approx.)	0.01

This assumes of course that the radioactive material stays where it is originally deposited. If some of it is buried e.g. by the continual turning over of debris, or is physically removed by rain or wind or by active measures of decontamination such as hosing down paved areas, then the dose rates will be much less than shown above.

Radioactive poisoning

78 This term is used to describe the results that may follow the introduction of radioactive materials into the body. Such materials may be taken into the body in various ways, for example:

(*a*) by breathing in contaminated dust;
(*b*) by eating contaminated food, or drinking contaminated water;
(*c*) by taking in contaminated dust into the blood stream through wounds or abrasions.

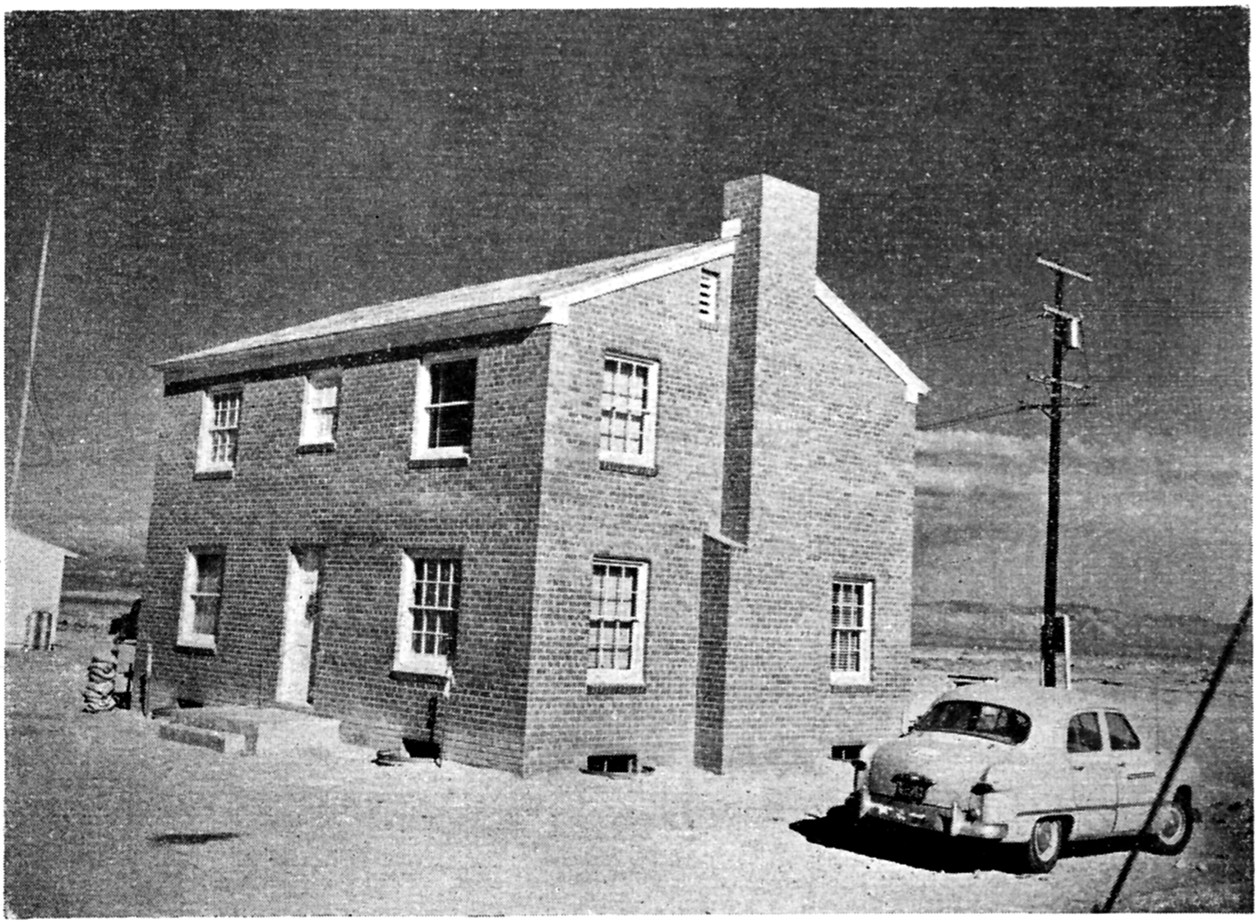

PLATE 20
Brick house at just under 1 mile from ground zero before test explosion, Nevada 1955.

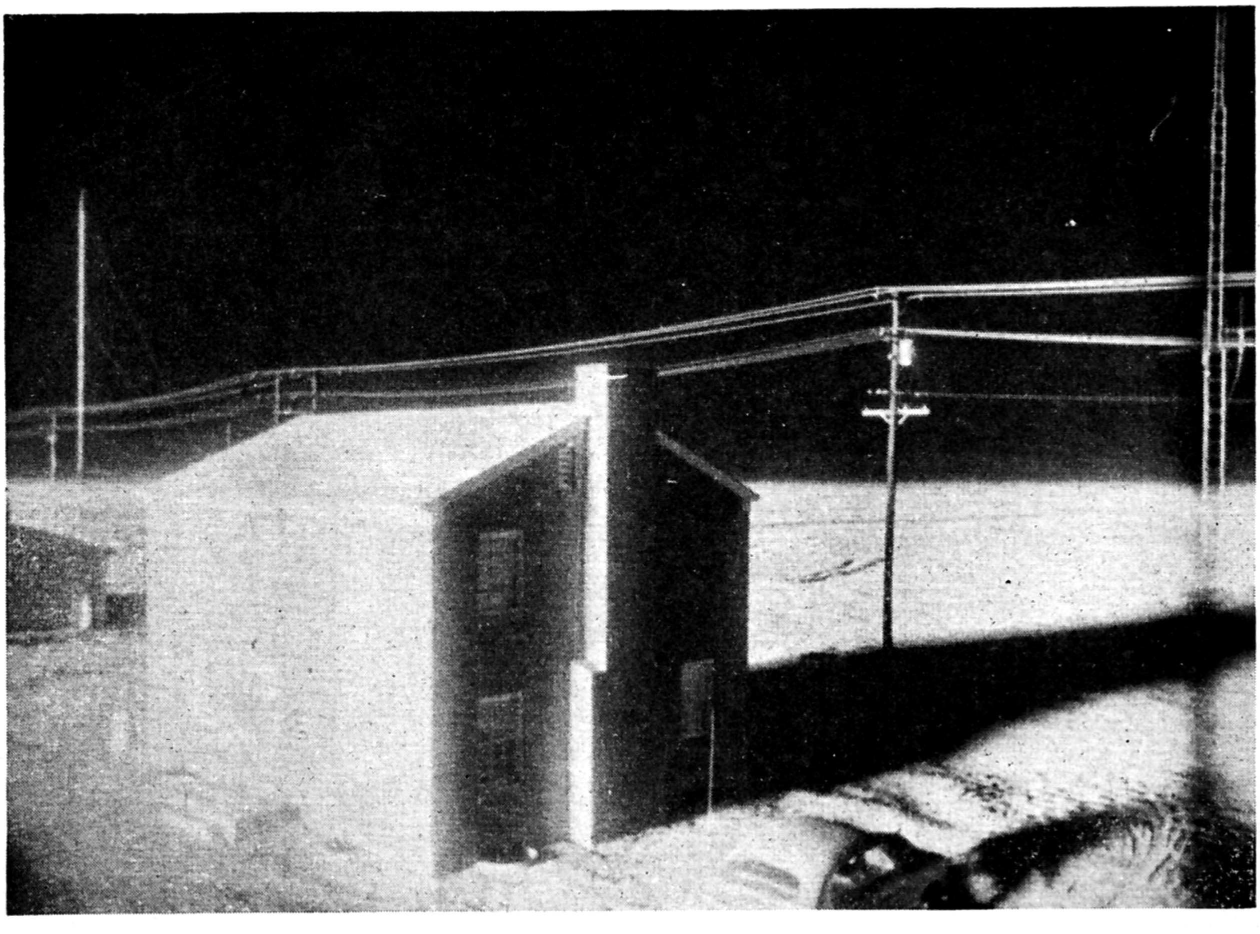

PLATE 21
The same house at the moment of the explosion (sequence 1).

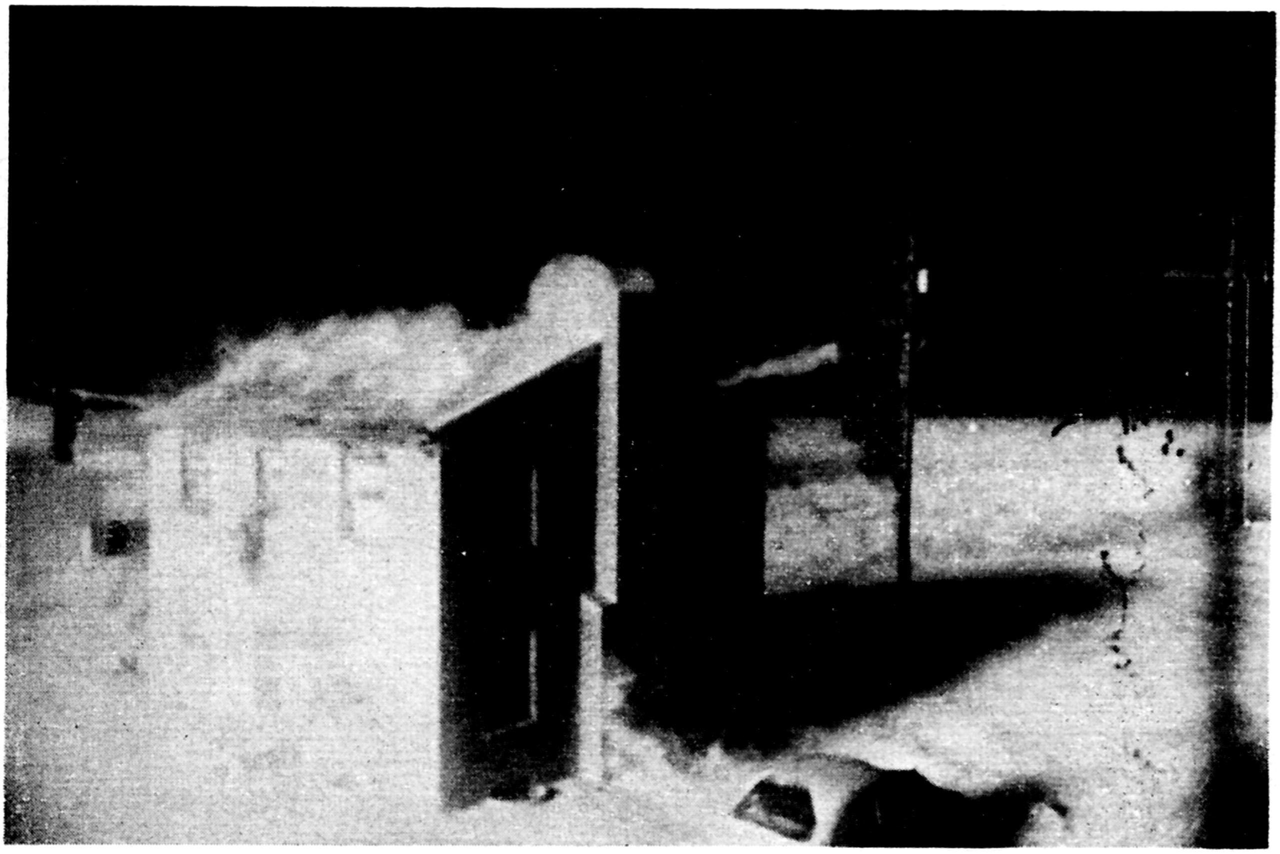

PLATE 22
Heat effect striking the house (sequence 2).

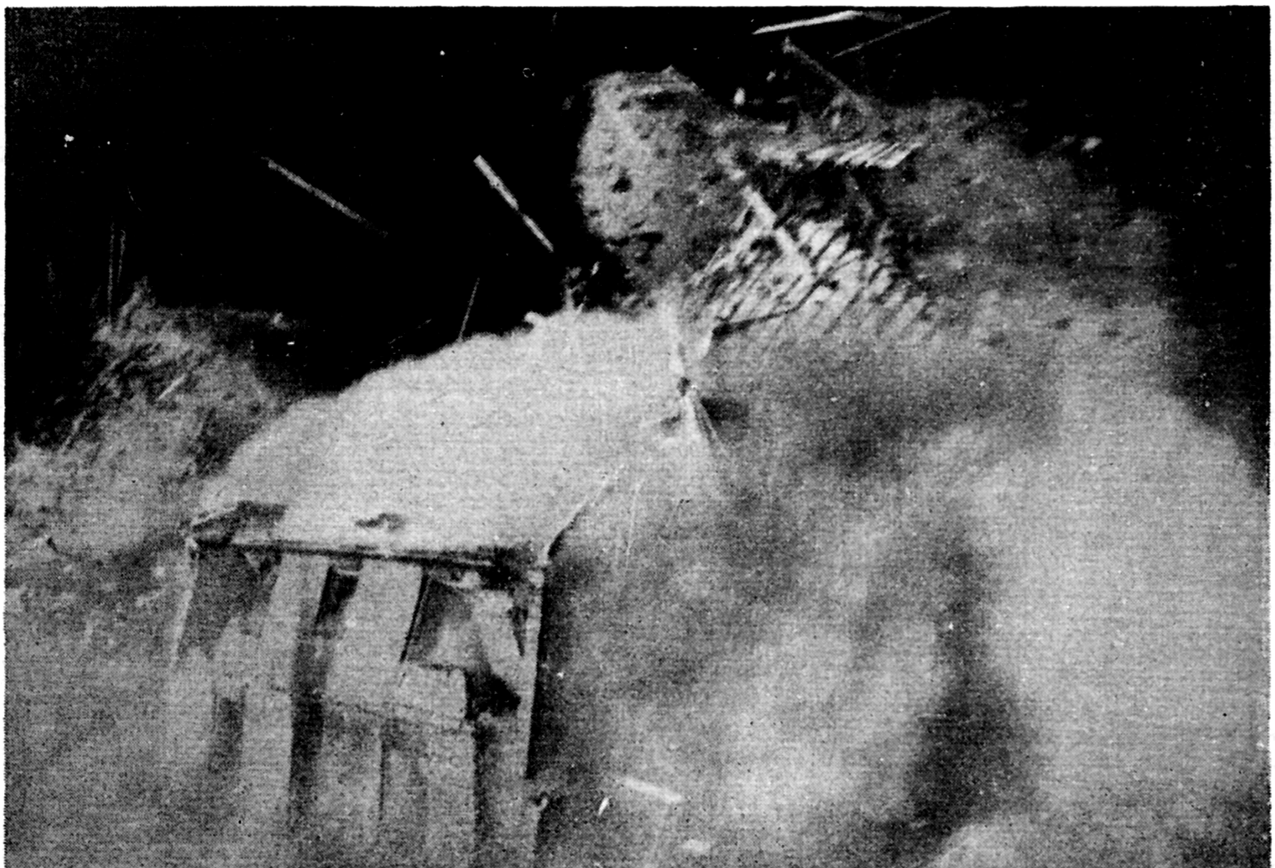

PLATE 23
Blast striking the house, causing it to 'explode' (sequence 3).

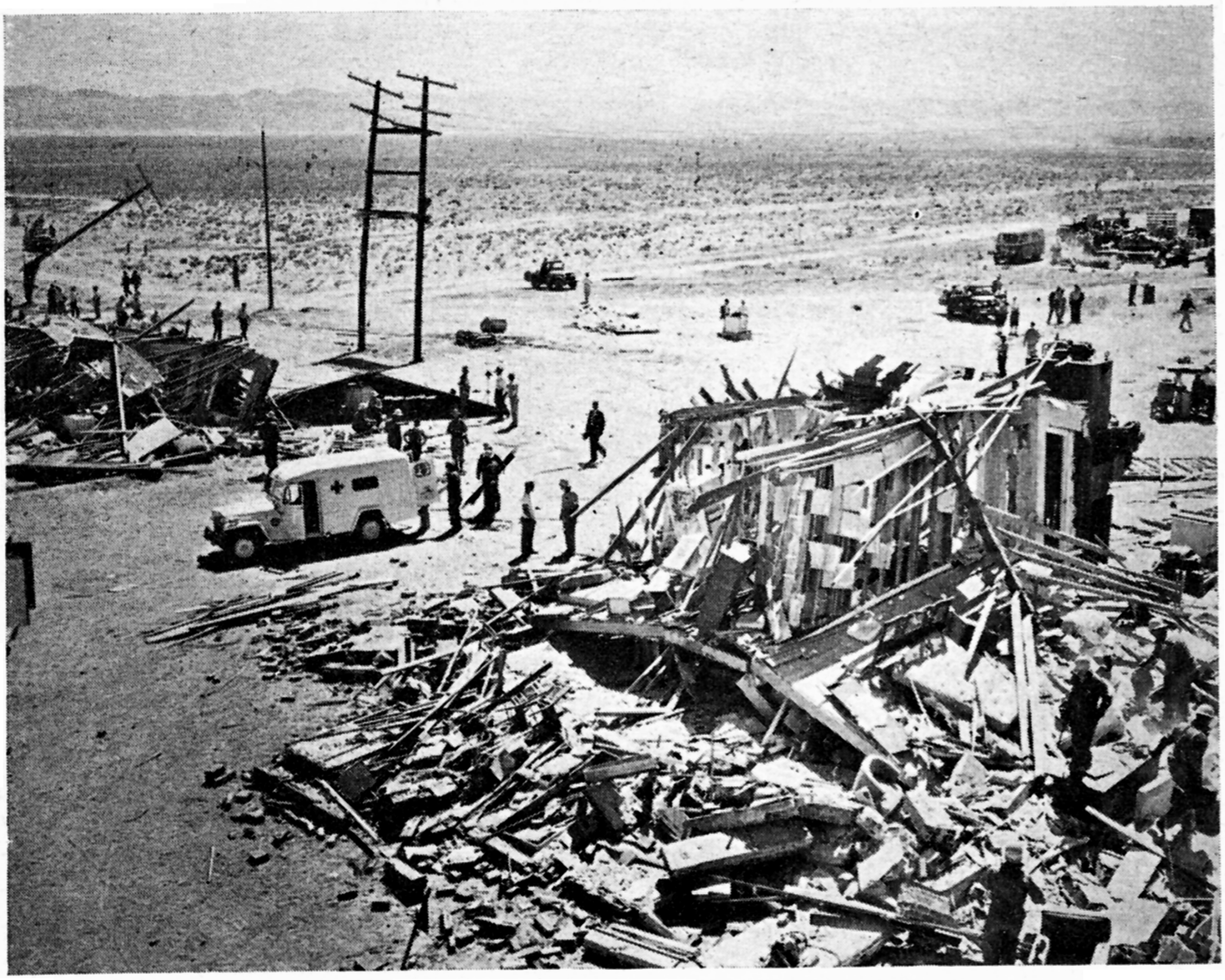

PLATE 24
All that remained of the house (sequence 4).

Windows of course provide no protection against gamma rays, so that it would be necessary to block them up with—for example—sandbags to the equivalent thickness of the walls.

Practical protection

88 Large buildings with a number of storeys, especially if they are of heavy construction, provide much better protection than small single-storey structures (see Figure 4). Houses in terraces likewise provide much better protection than isolated houses because of the shielding effect of neighbouring houses.

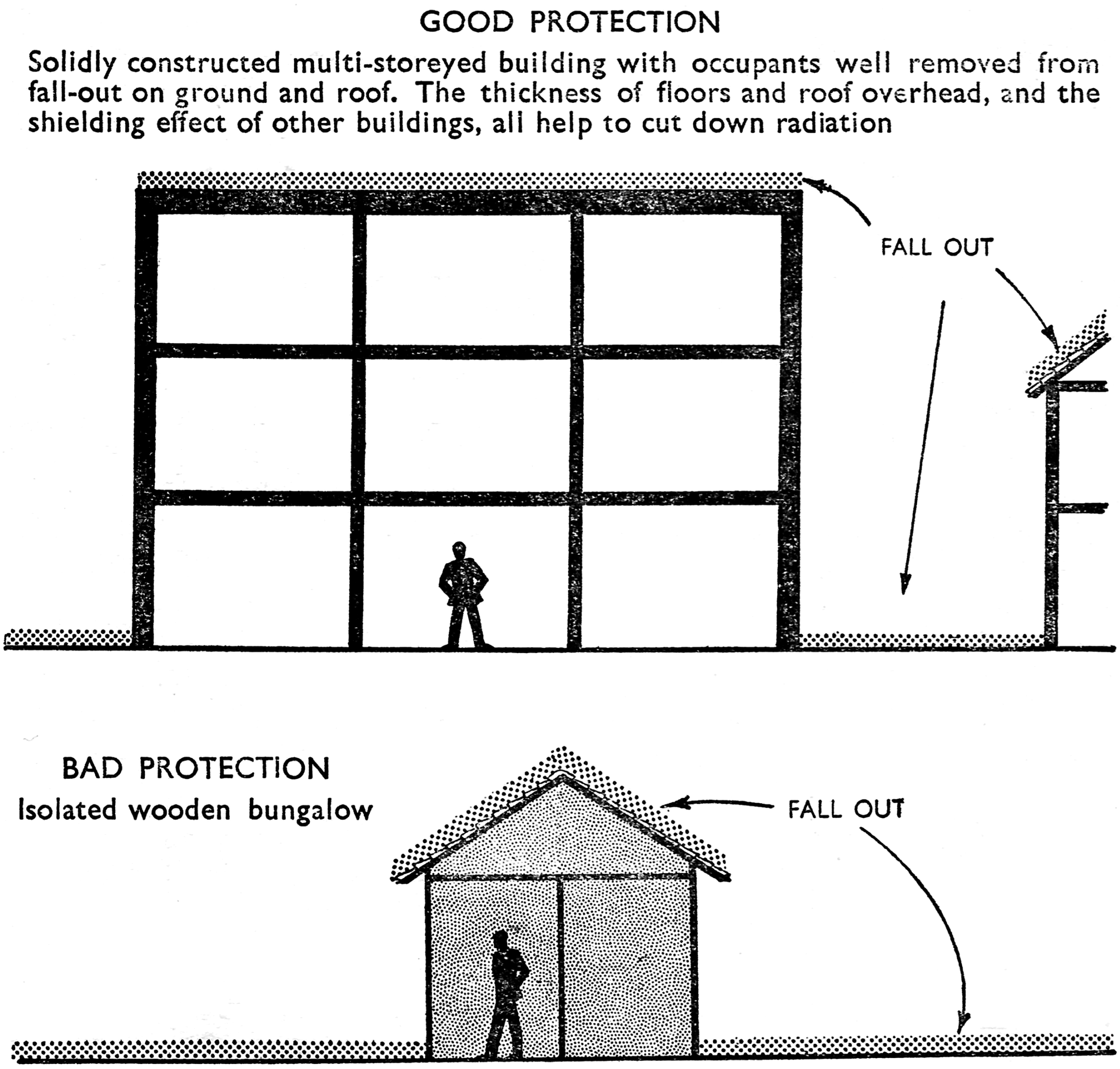

FIGURE 4

Examples of good and bad protection afforded by buildings against fall-out.

89 It is estimated that the protection factor (the factor by which the outside dose has to be divided to get the inside dose) of a ground floor room in a two-storey house ranges from 10 to about 50, depending on wall thickness and the shielding afforded by neighbouring buildings. The corresponding figures for bungalows are about 10–20, and for three-storey houses about 15–100. An average two-storey brick house in a built-up area gives a factor of 40, but basements, where the radiation from outside the house is attenuated by a very great thickness of earth, have protection factors ranging up to 200–300. A slit trench with even a light cover of boards or corrugated iron without earth overhead gives a factor of 7, and if 1 ft. of earth cover is added the

factor rises to 100. If the trench can be covered with 2 or 3 feet of earth then a factor of more than 200–300 can be obtained (see Figure 5).

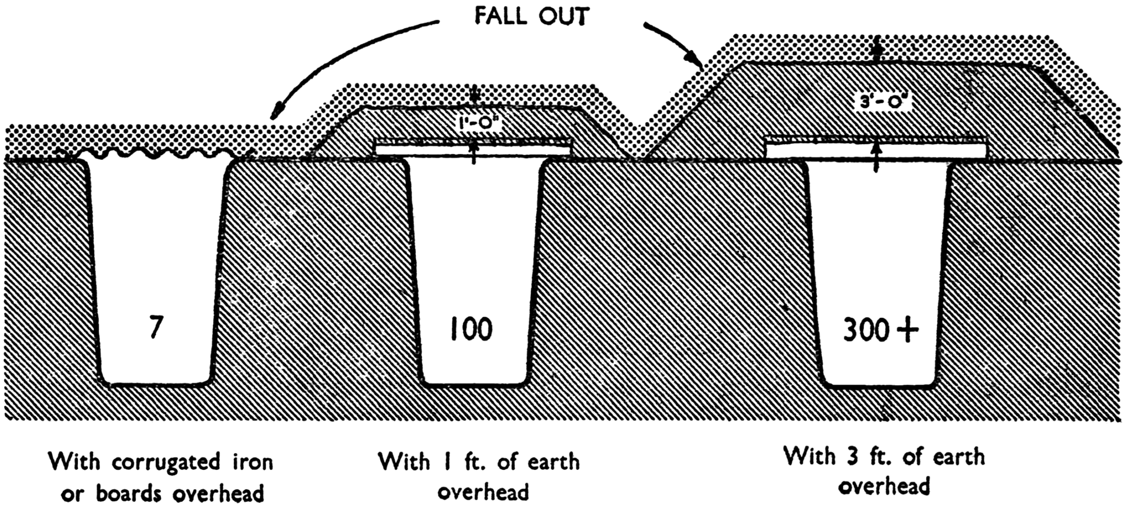

FIGURE 5
Protection factors in slit trenches (the factor by which the outside dose is divided to get the inside dose).

Choosing a refuge room

90 In choosing a refuge room in a house one would select a room with a minimum of outside walls and make every effort to improve the protection of such outside walls as there were. In particular the windows would have to be blocked up, e.g. with sandbags. Where possible, boxes of earth could be placed round an outside wall to provide additional protection, and heavy furniture (pianos, bookcases etc.) along the inside of the wall would also help. A cellar would be ideal. Where the ground floor of the house consists of boards and timber joists carried on sleeper walls it may be possible to combine the high protection of the slit trench with some of the comforts of the refuge room by constructing a trench under the floor.
Once a trap door had been cut in the floor boards and joists and the trench had been dug, there would be no further interference with the peace-time use of the room.

Estimated under-cover doses in the fall-out area

91 Taking an average protective factor of 40 for a two-storey house in a built-up area, the doses accumulated in 36 hours for the ranges referred to in the U.S. Atomic Energy Commission Report (paragraph 84) would have been:—

190	miles downwind	$7\frac{1}{2}$r	15 Megatons
160	,, ,,	$12\frac{1}{2}$r	Bravo 1954
140	,, ,,	20r	

which are all well below the lowest figure of 25r referred to in Table 1. At closer ranges along the axis of the fall-out, the doses accumulated in 36 hours would have been much higher, but over most of the contaminated area—with this standard of protection—the majority of those affected would have been saved from death, and even from sickness, by taking cover continuously for the first 36 hours.

Problems of control in the fall-out area

92 The administrative problems of warning, maintenance of communication with the public, control of exposure to radiation, evacuation where necessary, and maintenance of supplies in the fall-out area, are

5. **Radiation sickness**

Assume dose incurred in a single shift (3–4 hours) by the "average" man, over the whole body:—

25 roentgens		—No obvious harm.
100 „		—Some nausea and vomiting.
500 „		—Lethal to about 50 per cent. people (death up to 6 weeks later).
800 „	or more	—Lethal to all (death up to 6 weeks later).

Note: If dose spread uniformly over 2–3 days, then 60 roentgens could be incurred with no more effect than 25 roentgens in a single exposure of 3–4 hours.

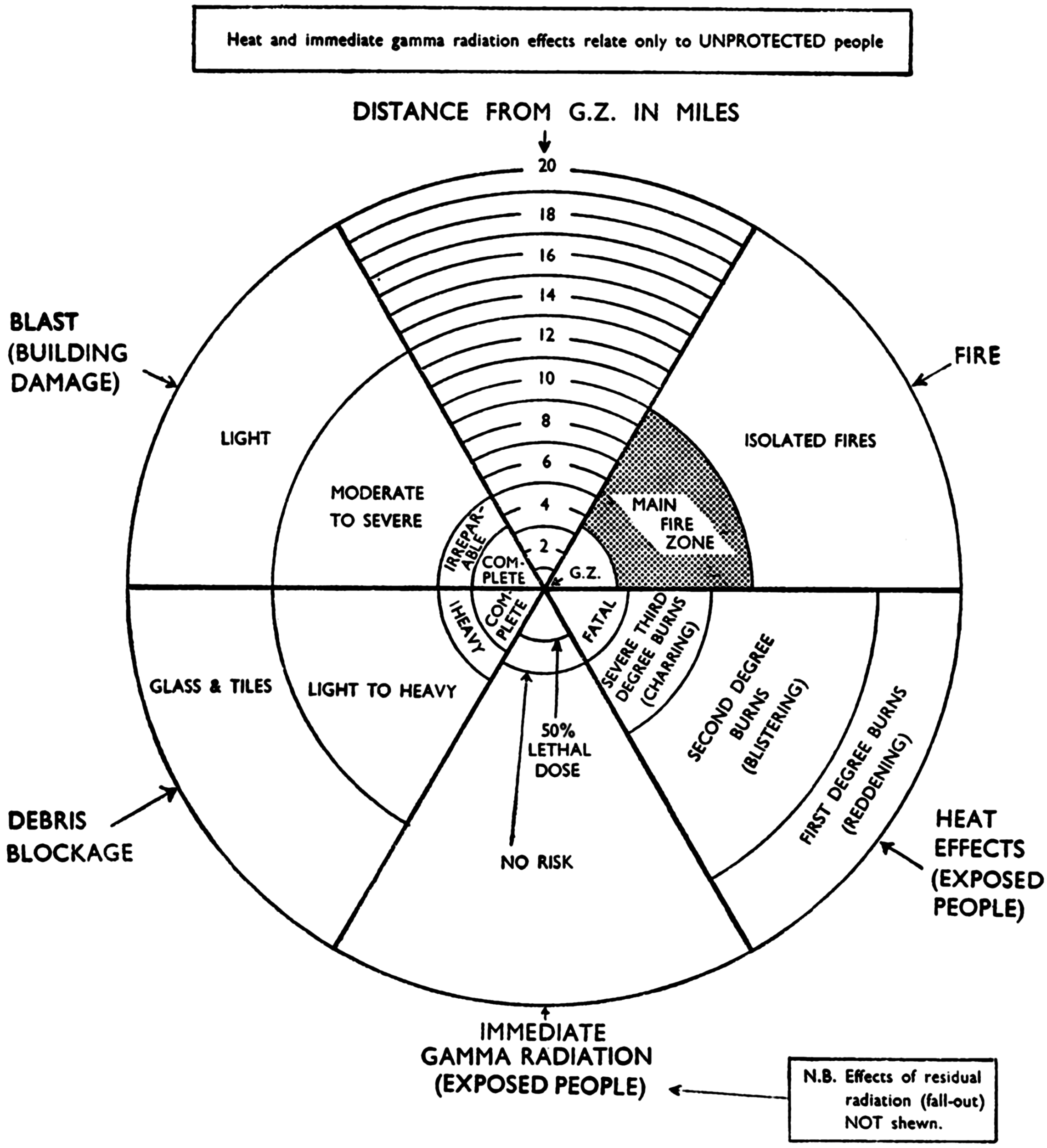

FIGURE 11

Combined effects (excluding residual radioactivity) from a 10 megaton ground burst bomb. Heat and immediate gamma radiation effects relate only to UNPROTECTED people.